

1    WHAT IS CLAIMED IS:

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3    1.    A method for separating mono-olefins comprising:

4        a) contacting a mixture comprising di-olefins and mono-olefins with an

5                olefin-complexing metal salt dissolved, dispersed, or suspended in

6                an ionic liquid;

7        b) maintaining such mixture in contact with such olefin-complexing

8                metal salt for sufficient time to selectively complex the di-olefins

9                over the mono-olefins to form a metal salt/olefin complex; and

10      c) separating the non-complexed mono-olefins.

11

12     2.    The method of claim 1, further comprising desorbing the di-olefins from

13                the metal salt/olefin complex.

14

15     3.    The method of claim 2, wherein said ionic liquid is capable of forming a

16                solution, suspension or dispersion with said olefin-complexing metal

17                salt.

18

19     4.    The method of claim 3, wherein the amount of said olefin-complexing

20                metal salt is adjusted so as to complex essentially only the di-olefins.

21

22     5.    The method of claim 1, wherein the metal salt comprises a Group IB

23                metal.

24

25     6.    The method of claim 5, wherein the metal salt is a copper salt.

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27     7.    The method of claim 6, wherein the metal salt is CuOTf.

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29     8.    The method of claim 5, wherein the metal salt is a silver salt.

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31     9.    The method of claim 8, wherein the metal salt is AgBF<sub>4</sub>.

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33     10.   The method of claim 1, wherein the mono-olefin and di-olefin-

1 containing mixture is a gaseous olefin-containing stream.

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3 11. The method of claim 1, wherein said mixture is contacted with said

4 olefin-complexing metal salt in a distillation apparatus.

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6 12. The method of claim 11, further comprising separating said non-

7 complexed mono-olefins by distillation in said distillation apparatus.

8

9 13. The method of claim 12, further comprising desorbing said di-olefins

10 from said metal salt/olefin complex by distillation in said distillation

11 apparatus.

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13 14. The method of claim 1, wherein said mixture is contacted with said

14 olefin-complexing metal salt in a system of one or more liquid mixers.

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16 15. The method of claim 14, further comprising separating said non-

17 complexed mono-olefins from said metal salt/olefin complex by

18 decantation.

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20 16. The method of claim 15, further comprising desorbing said di-olefins

21 from said metal salt/olefin complex in a regeneration apparatus.

22

23 17. The method of claim 16, further comprising sending the bottoms from

24 said regeneration apparatus to said system of liquid mixers.

25

26 18. The method of claim 1, wherein the mixture of mono- and di-olefins is

27 derived from wax hydrocracking, paraffin dehydrogenation, or

28 combinations thereof.

29

30 19. The method of claim 1, further comprising subjecting the mixture to

31 partial hydrogenation prior to the contacting step.

32

33 20. A method for separating mono-olefins comprising:

- 1        a) contacting a mixture comprising di-olefins and mono-olefins with an  
2                olefin-complexing metal salt dissolved, dispersed, or suspended in  
3                an ionic liquid;
- 4        b) maintaining such mixture in contact with such olefin-complexing  
5                metal salt for sufficient time to complex the mono-olefins and di-  
6                olefins with the olefin-complexing metal salt to form a metal  
7                salt/olefin complex; and
- 8        c) selectively desorbing the mono-olefins from the metal salt/olefin  
9                complex.
- 10
- 11      21. The method of claim 20, further comprising desorbing the di-olefins  
12                from the metal salt/olefin complex.
- 13
- 14      22. A method for separating mono-olefins and/or di-olefins comprising:  
15                a) contacting a mixture comprising di-olefins, mono-olefins and non-  
16                olefins with an olefin-complexing metal salt dissolved, dispersed or  
17                suspended in an ionic liquid;
- 18                b) maintaining such mixture in contact with such olefin-complexing  
19                metal salt for sufficient time to complex the mono-olefins and di-  
20                olefins with the olefin-complexing metal salt to form a metal  
21                salt/olefin complex;
- 22                c) separating the non-complexed non-olefins; and
- 23                d) selectively desorbing the mono-olefins from the metal salt/olefin  
24                complex.
- 25
- 26      23. The method of claim 22, further comprising desorbing the di-olefins  
27                from the metal salt/olefin complex.
- 28
- 29      24. The method of claim 23, wherein said ionic liquid is capable of forming  
30                a solution, suspension or dispersion with said olefin-complexing metal  
31                salt.
- 32
- 33      25. The method of claim 22, wherein the metal salt comprises a Group IB

1 metal.

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3 26. The method of claim 25, wherein the metal salt is a copper salt.

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5 27. The method of claim 26, wherein the metal salt is CuOTf.

6

7 28. The method of claim 25, wherein the metal salt is a silver salt.

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9 29. The method of claim 28, wherein the metal salt is AgBF<sub>4</sub>.

10

11 30. The method of claim 22, wherein the non-olefins comprise at least one

12 of paraffins, oxygenates, aromatics, or mixtures and combinations

13 thereof.

14

15 31. The method of claim 30, wherein the paraffins comprise cycloparaffins.

16

17 32. The method of claim 22, wherein the mono-olefins comprise at least

18 one of ethylene, propylene, or mixtures and combinations thereof.

19

20 33. The method of claim 32, wherein the ethylene is produced in an

21 ethylene cracker, an EP cracker, a naphtha cracker, or combinations

22 thereof.

23

24 34. The method of claim 22, wherein the olefins are produced in an

25 apparatus selected from the group consisting of an FCC unit, naphtha

26 hydrotreater, catalytic reformer, distillate hydrotreater, hydrocracker,

27 coker, RFCC unit, RDS unit and combinations thereof.

28

29 35. The method of claim 22, wherein the olefins are derived from paraffin

30 dehydrogenation, ethylene oligomerization, wax hydrocracking, or

31 combinations thereof.

32

33 36. The method of claim 22, wherein the olefins are produced in a Fischer-

1 Tropsch synthesis.

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3 37. The method of claim 22, wherein the mono-olefins are normal alpha

4 olefins derived from the ethenolysis of heavier internal olefins.

5

6 38. The method of claim 22, wherein the olefins are separated from a

7 recycle stream in a Fischer-Tropsch synthesis to reduce the amount of

8 olefins recycled from a Fischer-Tropsch unit to an upstream methane

9 reformer.

10

11 39. The method of claim 22, wherein the olefin-containing mixture is a

12 gaseous olefin-containing stream.

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14 40. The method of claim 22, wherein said mixture is contacted with said

15 olefin-complexing metal salt in a distillation apparatus.

16

17 41. The method of claim 40, further comprising separating said non-

18 complexed non-olefins from said metal salt/olefin complex by

19 distillation.

20

21 42. The method of claim 41, further comprising desorbing said mono-

22 olefins from said metal salt/olefin complex by distillation in said

23 distillation apparatus.

24

25 43. The method of claim 42, further comprising desorbing said di-olefins

26 from said metal salt/olefin complex by distillation in said distillation

27 apparatus.

28

29 44. The method of claim 22, wherein said mixture is contacted with said

30 olefin-complexing metal salt in a system of one or more liquid mixers.

31

32 45. The method of claim 44, further comprising separating said non-

33 complexed non-olefins from said metal salt/olefin complex by

1                   decantation.

2

3   46. The method of claim 45, further comprising desorbing said mono-

4                   olefins from said metal salt/olefin complex in a regeneration apparatus.

5

6   47. The method of claim 46, further comprising desorbing said di-olefins

7                   from said metal salt/olefin complex in said regeneration apparatus.

8

9   48. The method of claim 47, further comprising sending the bottoms from

10                  said regeneration apparatus to said system of liquid mixers.

11

12   49. The method of claim 22, further comprising purifying the olefin-

13                  containing mixture before the contacting step to remove sulfur,

14                  acetylinics, oxygenates, and other heteroatoms.

15

16   50. A method for separating mono-olefins and/or di-olefins comprising:

17                  a) contacting a mixture comprising di-olefins, mono-olefins and non-

18                  olefins with an olefin-complexing metal salt dissolved, dispersed or

19                  suspended in an ionic liquid;

20                  b) maintaining such mixture in contact with such olefin-complexing

21                  metal salt for sufficient time to selectively complex the di-olefins

22                  over the mono-olefins to form a first metal salt/olefin complex;

23                  c) separating the non-complexed mono-olefins and non-olefins;

24                  d) desorbing the di-olefins from the first metal salt/olefin complex;

25                  e) contacting the non-complexed mono-olefins and non-olefins with

26                  the olefin-complexing metal salt;

27                  f) maintaining such non-complexed mono-olefins and non-olefins in

28                  contact with such olefin-complexing metal salt for sufficient time to

29                  complex the mono-olefins to form a second metal salt/olefin

30                  complex; and

31                  g) separating the non-complexed non-olefins.

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33   51. The method of claim 50 further comprising desorbing the mono-olefins

1 from the second metal salt/olefin complex.

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3 52. The method of claim 51, wherein the amount of said olefin-complexing

4 metal salt is adjusted so as to complex essentially only the di-olefins.

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6 53. The method of claim 1, wherein said ionic liquid is comprised of anions

7 and cations, wherein;

8 said anions are selected from the group consisting of halide salts,

9 metal anions, chloroaluminate, bromoaluminate, gallium chloride,

10 tetrafluoroborate, tetrachloroborate, hexafluorophosphate, nitrate,

11 trifluoromethane sulfonate, methylsulfonate, *p*-toluenesulfonate,

12 hexafluoroantimonate, hexafluoroarsenate, tetrachloroaluminate,

13 tetrabromoaluminate, perchlorate, hydroxide anion, copper dichloride

14 anion, iron trichloride anion, antimony hexafluoride, copper dichloride

15 anion, zinc trichloride anion, lanthanum anion, potassium anion, lithium

16 anion, nickel anion, cobalt anion, manganese anion, and combinations

17 and mixtures thereof; and

18 said cations are selected from the group consisting of cyclic and non-

19 cyclic quaternary ammonium cations, alkylammoniums, pyridiniums,

20 substituted pyridiniums, N-alkylpyridiniums, imidazoliums, substituted

21 imidazoliums, N,N'-dialkylimidazoliums, pyrroliniums, substituted

22 pyrroliniums, phosphoniums, alkylphosphoniums, arylphosphoniums,

23 1-butyl-3-methylimidazolium, N-hexylpyridinium, 1-hexyl-3-

24 methylimidizolium, (C<sub>8</sub>H<sub>17</sub>)<sub>3</sub>MeN, Bu<sub>2</sub>Me<sub>2</sub>N, and mixtures and

25 combinations thereof.

26

27 54. The method of claim 22, wherein said ionic liquid is comprised of

28 anions and cations, wherein;

29 said anions are selected from the group consisting of halide salts,

30 metal anions, chloroaluminate, bromoaluminate, gallium chloride,

31 tetrafluoroborate, tetrachloroborate, hexafluorophosphate, nitrate,

32 trifluoromethane sulfonate, methylsulfonate, *p*-toluenesulfonate,

33 hexafluoroantimonate, hexafluoroarsenate, tetrachloroaluminate,

1       tetrabromoaluminate, perchlorate, hydroxide anion, copper dichloride  
2       anion, iron trichloride anion, antimony hexafluoride, copper dichloride  
3       anion, zinc trichloride anion, lanthanum anion, potassium anion, lithium  
4       anion, nickel anion, cobalt anion, manganese anion, and combinations  
5       and mixtures thereof; and  
6       said cations are selected from the group consisting of cyclic and non-  
7       cyclic quaternary ammonium cations, alkylammoniums, pyridiniums,  
8       substituted pyridiniums, N-alkylpyridiniums, imidazoliums, substituted  
9       imidazoliums, N,N'-dialkylimidazoliums, pyrroliniums, substituted  
10      pyrroliniums, phosphoniums, alkylphosphoniums, arylphosphoniums,  
11      1-butyl-3-methylimidazolium, N-hexylpyridinium, 1-hexyl-3-  
12      methylimidizolium,  $(C_8H_{17})_3MeN$ ,  $Bu_2Me_2N$ , and mixtures and  
13      combinations thereof.

14

15      55. A method for optimizing the method of claim 1, comprising preparing a  
16      combinatorial library including a plurality of combinations of ionic  
17      liquids and olefin-complexing metal salts, and evaluating the library for  
18      its ability to separate di-olefins from a mixture comprising mono-olefins  
19      and di-olefins.

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21      56. A method for optimizing the method of claim 22, comprising preparing  
22      a combinatorial library including a plurality of combinations of ionic  
23      liquids and olefin-complexing metal salts, and evaluating the library for  
24      its ability to separate olefins from a mixture comprising olefins and  
25      non-olefins.